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U. S. NAVAL AIR ENGINEERING CENTER

PHILADELPHIA, PENNSYLVANIA

AERONAUTICAL MATERIALS LABORATORY

REPORT NO. NAEC-AML-2536 DATE 5 December 1966

OCEANOGRAPHIC EFFECTS ON PLASTIC ENGINEERING MATERIALS

ASSIGNMENT 12 -2(1D) UNDER
AIRTASK A32 523 001/200 1/R007 01 01

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ABSTRACT

The continuing effort to evaluate oceanographic environment effects on a wide spectrum of plastic engineering materials, reinforced laminates and other plastics, has been in progress. Submersible Test Unit I-2 test panel array, which is discussed, represents one segment of this continuing effort. This panel array was submerged October 1963 for 751 days at a depth of approximately 5,640 feet in the Port Hueneme Pacific Ocean area.

Laboratory studies, after exposure, indicated that, in general, deep sea immersion adversely affected the mechanical properties of most of the materials.

I. INTRODUCTION

A. The study described herein represents one segment of the continuing effort of the Aeronautical Materials Laboratory's endeavor in evaluating deep oceanographic effects on a wide spectrum of polymeric materials. This particular effort is directed principally toward exposures at various depths of the ocean which have been in progress.

B. The principal objective of this portion of the studies is to gather long term engineering data on the relative performance of plastic materials in various ocean environments so that designers of weapon system components will have reliable information on which to base their design of equipment for service under these environments.

II. GENERAL DISCUSSIONS

A. In recent years interest in the ocean depths and the study of new engineering materials that may be utilized at these depths have been increasing. Among these new materials being considered, for such applications as weapon systems, are organic polymers with which this report is concerned.

B. Through the cooperation of the U. S. Naval Civil Engineering Laboratory, Port Hueneme, California, a series of Naval Air Engineering Center - Aeronautical Materials Laboratory specimens are being deep sea exposed at contrasting depths and for various time durations.

C. This report discusses the test panel array (Submersible Test Unit I-2) of commercial plastic reinforced laminates and other plastics, in the relaxed and stressed conditions, which was submerged in October 1963 at a depth of approximately 5,640 feet for 751 days in the Port Hueneme Pacific Ocean area.

D. The selection of material for exposure was based on their presently intended application and the performance data previously submitted by the manufacturer or determined by the Naval Air Engineering Center, Aeronautical Materials Laboratory, Plastics Branch. Appendix A, Table 3, describes these materials.

E. The study of the effects of oceanographic exposure on materials is a problem complicated by the enormously complex environmental variables in the properties of the sea. Among the more important variables are such properties as salinity, temperature, pressure, hydrogen ion concentration, dissolved oxygen,flow currents and types of marine organisms, all of which vary with the depth, site and duration of exposure.

F. However, it is hoped that for any one particular depth and site, the continuous changes in ocean conditions are not so severe as to preclude reproducibility of tests within certain reasonable limits.

III. METHOD OF TESTS

A. Two groups of commercial plastic specimens, low pressure laminates and cured resins, size 5½ inches x 12 inches x 1/8 inch, were mounted in a test jig such that a condition of flexural load of 40-55 pounds total constantly prevailed and below each was mounted a duplicate specimen in the relaxed state (see appendix B, Figures 1 and 2).

B. Each set was held together by phenolic pegs at both ends of the specimens, and all edges in the total assembly were sealed with an epoxy resin, Chrysler Cycleweld C-14, to prevent or hinder deterioration through any weaknesses that may have been incurred during the cutting of each specimen and jig component.

C. For the acrylic specimen, a flexural load of only 12 pounds total was impressed because of the limiting nature of the jig construction.

D. Specimens were submerged to a depth of 5,640 feet for 751 days duration at the Port Hueneme Pacific Ocean area on 2 October 1963 under the following environmental conditions:

Location	33° 44'N, 120° 45'W
Pressure	2482 psi
Salinity	34.59 parts per thousand
Oxygen	2.14 parts per million
Temperature	36.3°F
pH	7.48
Current	less than 0.5 knots
Sediment	green mud to rocks

Specimens were retrieved 22 October 1965.

E. Upon retrieval, the entire assembly was forwarded to the Naval Air Engineering Center in the "as is" condition enclosed in plastic bags. Drying out of the specimens occurred during transit and the interval between disassembly and mechanical testing was such that the curvatures in the stressed specimens were difficultly discernible.

F. Specimen sizes, as cut from the exposed panels, and test procedures for mechanical testing are as detailed in MIL-STD-401A. Values obtained were based on the average of 3 to 6 specimens.

IV. TEST RESULTS

The results of mechanical testing are tabulated in Appendix A, Tables 1 and 2.

V. OBSERVATIONS

A. Specimens on receipt had no apparent surface effects except for a light deposit of what appeared to be marine plant life adhering to the surface of all the specimens and jig in a dendritic pattern. (See Appendix B, Figures 1, 2, 3 and 4.

B. Room temperature mechanical properties tested after exposure indicated the following characteristics:

1. In general, flexural strengths decreased after exposure except for the acrylic and phenolic #3 relaxed specimens which exhibited a slight increase in strength over the control. The values for these specimens demonstrating the increase were based on the average of four specimens. In either case, the fact that the flexural values of three of the four specimens were greater than the average for the respective control, reflects the degree of reliability of the observation.

The values noted for all the stressed specimens indicated that the oceanographic exposure effected loss in flexural strength ranging from 1.5% for phenolic #3 to 12.4% for phenolic #2.

2. Except for phenolic #3 which showed an increase for relaxed and stressed specimens, modulus of elasticity values dropped for all the specimens, relaxed as well as stressed.

3. Tensile strength increases occurred for the polyester and epoxy, both in the relaxed and stressed condition; and for the acrylic in only the stressed state.

4. All specimens incurred loss in compressive strength with those under stress, excepting phenolic #2, exhibiting a lesser degree of loss than those relaxed.

VI. CONCLUSIONS

A. Since this is a continuing effort in evaluating deep sea submergence effects at various depths and for different time durations, note will be made of the oceanographic effects on each individual type of material versus exposure. However, except for the results discussed in each respective report, it is premature at this stage of the effort to justifiably compare the various exposures since there has not been a significant number of them as yet and, additionally, not all of the exposures involve the same types of materials.

B. For this array of specimens deep sea immersion for 751 days adversely affected the mechanical properties of most of the materials.

C. The supposed enhancement of mechanical properties observed after exposure may be explained by the fact that control values were determined much in advance of values for the exposed specimens. During this interval it is possible that gradual postcuring may have occurred before, during, or after exposure to yield the higher strength values and any loss in strength incurred during exposure may be overshadowed by the increase due to this postcure.

VII. RECOMMENDATIONS

A. It is recommended that control specimens be tested, if possible, concurrently with the exposed specimens so as to prevent differences in test data due to any time interval effects such as postcuring.

B. It is also recommended that a significant number of exposures be made testing the same types of materials, providing sufficient coupons of these materials are available.

C. Also recommended is that the time interval between retrieval and laboratory tests be reduced as much as possible to prevent unreliability of results due to recovery or deterioration of mechanical properties during the time interval.

D. Retrieved specimens should be kept immersed in sea water until mechanical tests are initiated.

VIII. FUTURE PLANS

A. The same types of plastic materials as in previous exposures, if available, will be submitted for immersion until a significant number of exposures is obtained.

B. New types of plastic engineering materials will also be studied either concurrently with previous types or separately.

C. Specimens of the same types of materials as in STU 1-4 for shallow water immersion have been prepared and at present await consignment to the appropriate facility.

D. A type of test has been devised and will be applied to determine quantitatively the degree of sea water absorption of exposed specimens. This method of test should not be affected by the drying out of the specimens during the period between retrieval and laboratory testing.

IX. APPENDIX A

MECHANICAL TESTS ON OCEANOGRAPHIC SPECIMENS

Tests(1)	1/8" Acrylic Control	1/8" Acrylic Exposed A	1/8" Acrylic Exposed B	Polyester Control	Polyester Exposed A	Polyester Exposed B	Phenolic 1 Control	Phenolic 1 Exposed A	Phenolic 1 Exposed B
Room Temperature Flexural Strength (psi)	17,050	17,320	16,645	67,690	64,575	63,535	66,645	61,170	62,085
Modulus of Elasticity (psi)	0.49 x 10^6	0.47 x 10^6	0.44 x 10^6	2.88 x 10^6	2.83 x 10^6	2.76 x 10^6	3.77 x 10^6	3.65 x 10^6	3.62 x 10^6
Tensile Strength (psi)	9,915	8,205	10,375	55,520	55,750	57,625	41,405	39,625	38,670
Compression Strength (psi)	21,320	16,785	17,145	43,705	33,320	34,085	65,860	43,475	46,805

Tests(1)	Phenolic Control	Phenolic Exposed A	Phenolic Exposed B	Epoxy Control	Epoxy Exposed A	Epoxy Exposed B	Phenolic 3 Control	Phenolic 3 Exposed A	Phenolic 3 Exposed B	Phenolic Plates of Jig Exposed A	Phenolic Plates of Jig Exposed B	Phenolic Plates of Jig Exposed C
Room Temperature Flexural Strength (psi)	81,220	72,010	71,170	83,600	72,430	74,495	76,130	76,350	75,000	19,130	19,510	20,215
Modulus of Elasticity (psi)	2.68 x 10^6	3.37 x 10^6	3.50 x 10^6	3.25 x 10^6	3.09 x 10^6	3.21 x 10^6	3.29 x 10^6	3.55 x 10^6	3.38 x 10^6	0.58 x 10^6	0.59 x 10^6	0.64 x 10^6
Tensile Strength (psi)	49,005	40,745	42,580	48,910	59,840	81,000	51,930	43,770	49,970			
Compression Strength (psi)	62,970	50,410	47,210	72,000	43,550	31,795	60,615	48,555	44,660	22,285	24,590	23,035

Notes: (1) Tested in accordance with MIL-STD-401A

(2) "A" denotes specimens in the relaxed condition
"B" denotes specimens under flexural stress

Table 1

COMPARISON OF ROOM TEMPERATURE MECHANICAL PROPERTIES - CONTROL AND EXPOSED SPECIMENS

Oceanographic Specimens	Flexural Strength			Modulus of Elasticity			Tensile Strength			Compressive Strength		
	Relaxed vs Control %	Stressed vs Control %	Stressed vs Relaxed %	Relaxed vs Control %	Stressed vs Control %	Stressed vs Relaxed %	Relaxed vs Control %	Stressed vs Control %	Stressed vs Relaxed %	Relaxed vs Control %	Stressed vs Control %	Stressed vs Relaxed %
1/8" Acrylic	1.6 Gain	2.4 Loss	3.9 Loss	4.4 Loss	11.1 Loss	7.0 Loss	17.3 Loss	4.6 Gain	26.5 Gain	21.3 Loss	19.6 Loss	2.3 Gain
Polyester	4.6 Loss	6.1 Loss	1.6 Loss	1.7 Loss	4.2 Loss	2.5 Loss	0.4 Gain	3.8 Gain	3.4 Gain	23.8 Loss	22.0 Loss	2.3 Gain
Phenolic (1)	8.2 Loss	6.8 Loss	1.0 Gain	3.2 Loss	4.0 Loss	0.8 Loss	4.3 Loss	6.6 Loss	2.4 Loss	34.0 Loss	28.9 Loss	7.7 Gain
Phenolic (2)	11.3 Loss	12.4 Loss	1.2 Loss	8.4 Loss	4.9 Loss	3.9 Gain	16.9 Loss	13.1 Loss	4.5 Gain	19.9 Loss	25.0 Loss	6.4 Loss
Epoxy	13.4 Loss	10.9 Loss	2.9 Gain	4.9 Loss	1.2 Loss	3.9 Gain	22.4 Gain	65.6 Gain	35.4 Gain	39.5 Loss	28.1 Loss	18.9 Gain
Phenolic (3)	2.9 Gain	1.5 Loss	1.8 Loss	7.9 Gain	2.7 Gain	4.8 Loss	4.2 Loss	3.8 Loss	0.4 Gain	19.9 Loss	26.3 Loss	8.0 Loss

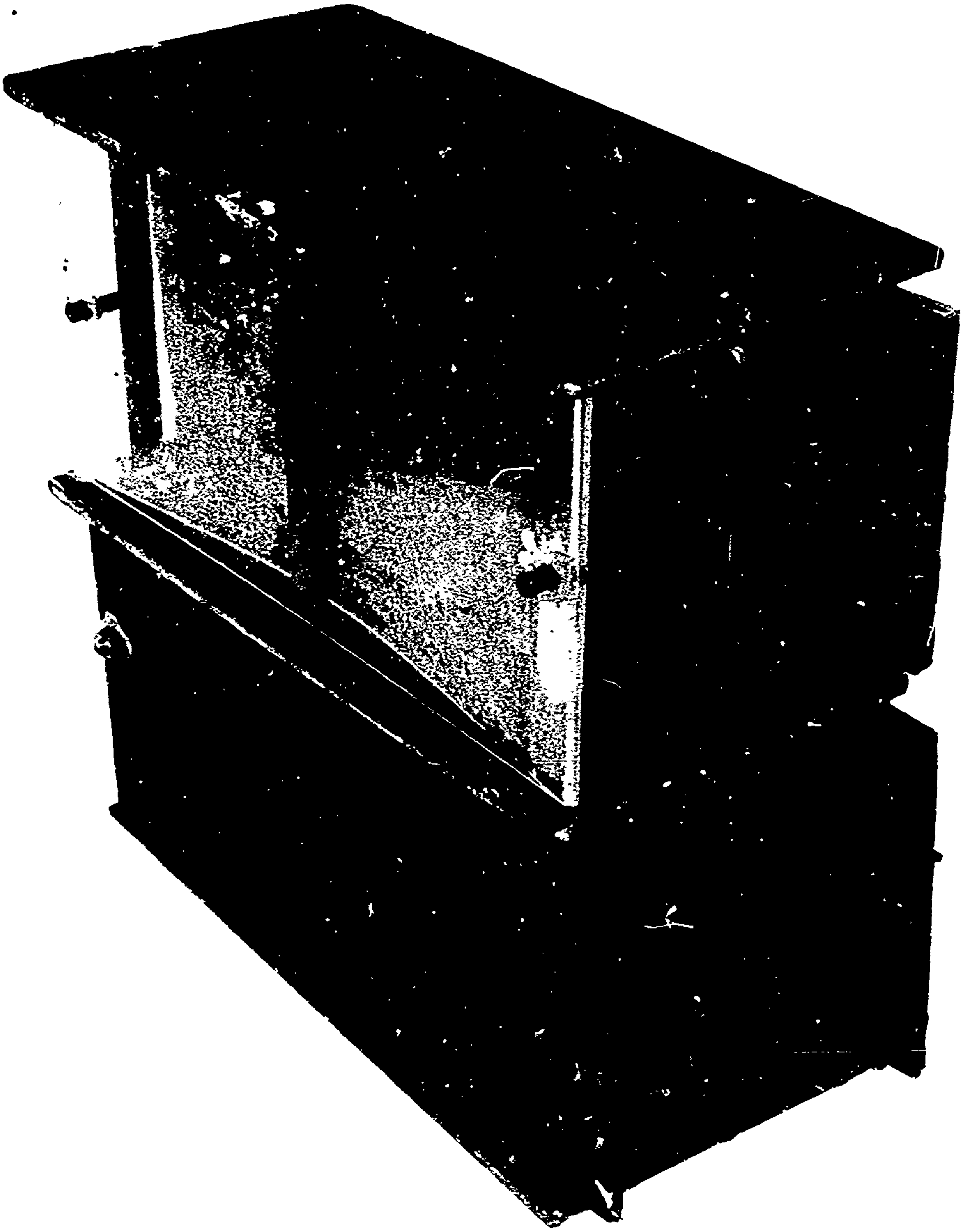
Table 2

DESCRIPTION OF MATERIALS TESTED

1.	1/8" Acrylic	EVR-KLEER Type II UVA Cast Optics Corp.
2.	Polyester	Polyester Glass Reinforced Laminate Pleogen 1321 American Petro Chemical Corp.
3.	Phenolic 1	Phenolic Glass Reinforced Laminate Plyophen 98-573 Reichold Chemical Inc.
4.	Phenolic 2	Phenolic Glass Reinforced Laminate Plyophen 98-583 Reichold Chemical Inc.
5.	Phenolic 3	Phenolic Glass Reinforced Laminate EC-200 Evercoat, Chemicals, Inc.
6.	Epoxy	Epoxy Glass Reinforced Laminate Trevarno 161 Coast Manufacturing and Supply Co.
7.	Phenolic Plate	

Table 3

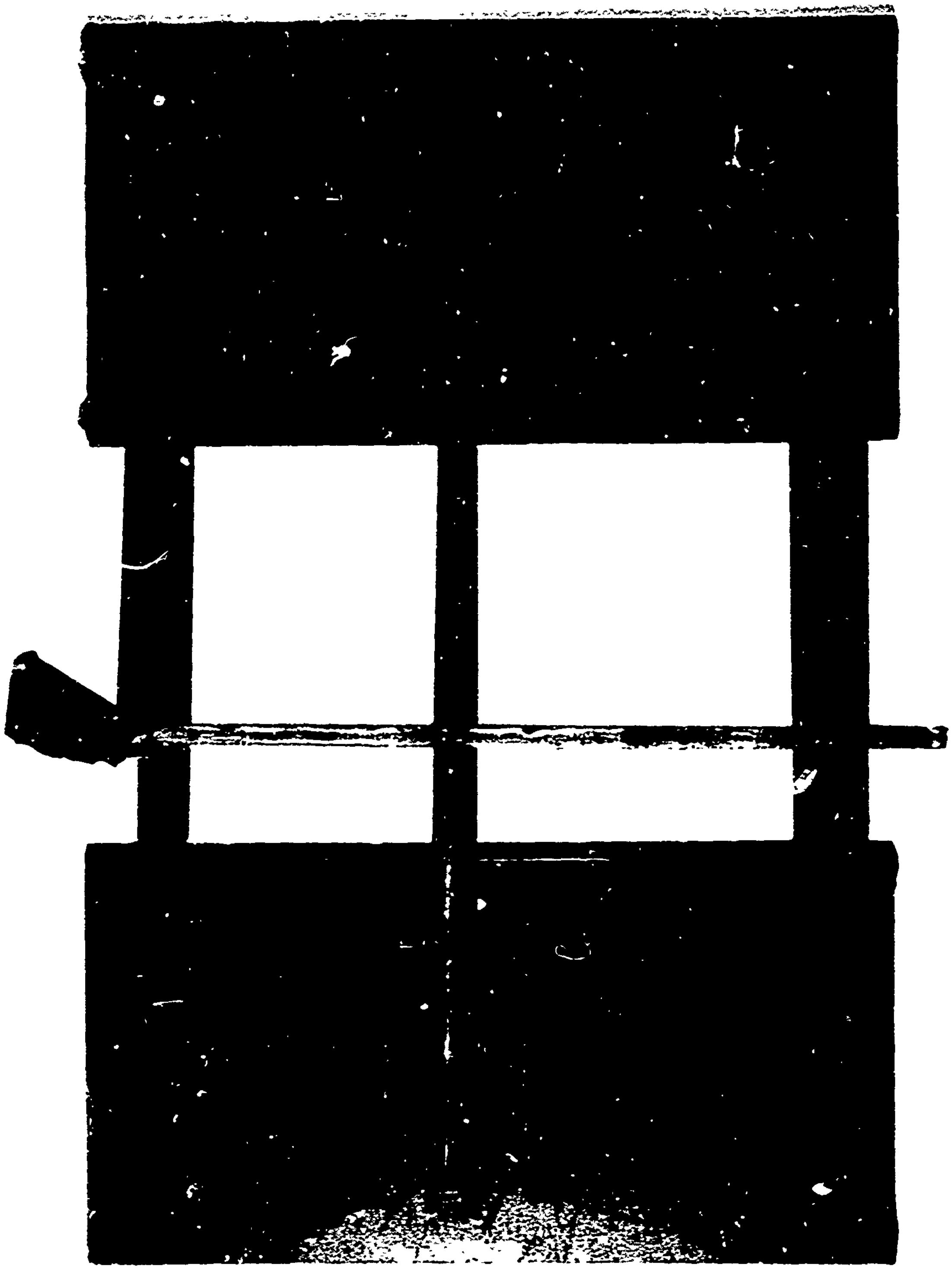
X. APPENDIX B



TOTAL ASSEMBLY - JIG AND TWELVE TEST SPECIMENS
PRIOR TO DISASSEMBLY FOR TESTING

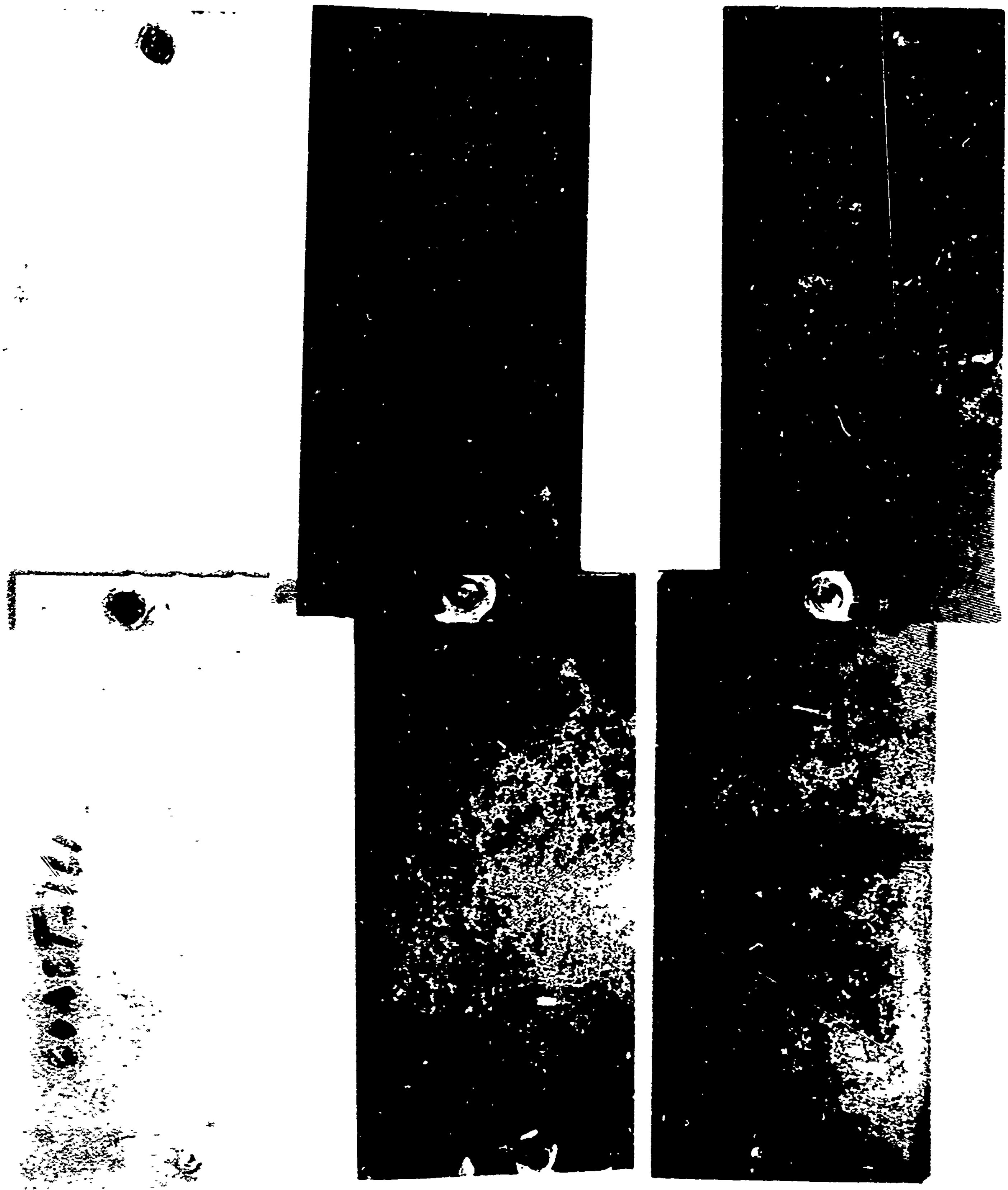
PHOTO NO: CAN-374566(L)-3-66

Figure 1



JIG DISASSEMBLED WITH SPECIMENS REMOVED

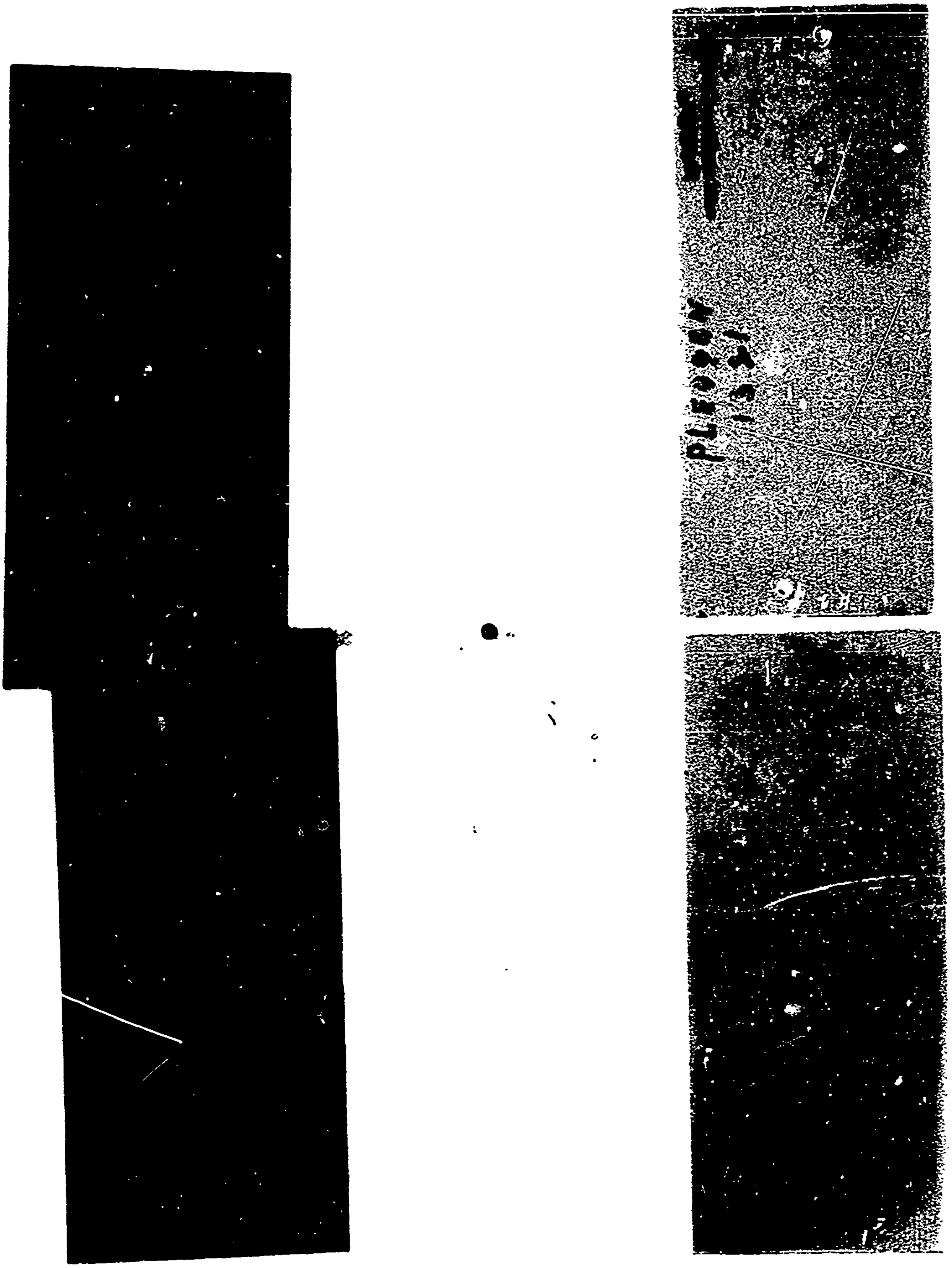
PHOTO NO: CAN-374567(L)-3-66 Figure 2



SPECIMENS REMOVED FROM JIG SHOWING
EPOXY, PHENOLIC #3, AND PHENOLIC #2 SPECIMENS RESPECTIVELY

PHOTO NO: CAN-374568(L)-3-56

Figure 3



SPECIMENS REMOVED FROM JIG SHOWING
PHENOLIC #1, ACRYLIC, AND POLYESTER SPECIMENS RESPECTIVELY

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Figure 4

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13. ABSTRACT

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